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OCTOBER 24, 1983

CHEMICAL & ENGINEERING

NEWS

- Petrochemicals finally rebound

A Key Chemicals Review
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Cover: Arco Chemical's olefins and aromatics complex at Channelview, Tex.

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CHEMICAL & ENGINEERING
NEWS
OCTOBER 24, 1983

News of the Week

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News Focus

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Basic Petrochemicals Swing into Long-Awaited Recovery

Doing much better in 1983 than forecast, basic olefins and aromatics head toward another solid gain in 1984; some supplies could get snug

Bruce F. Greek, C&EN Houston

U.S. petrochemicals are finally on the move again. These long-suffering big-volume organics produced tanker loads of red ink for their owners in the early 1980s but now are well on the way toward financial health. They have outstripped most forecasts for this year and seem certain to make further gains in 1984.

Production growth for the five major petrochemicals covered in the following pages—ethylene, propylene, butadiene, benzene, and *p*-xylene—reached double-digit numbers year-to-year in the second and third quarters after a slow start in the first. Production is not yet back to the old highs, but it is headed that way. For example, new highs are due for ethylene and propylene in 1984.

Even though production growth has slowed since early summer, the upward tilt is expected to continue through 1984. Demand growth has slowed, too, but is still fairly strong—possibly at a more sustainable level.

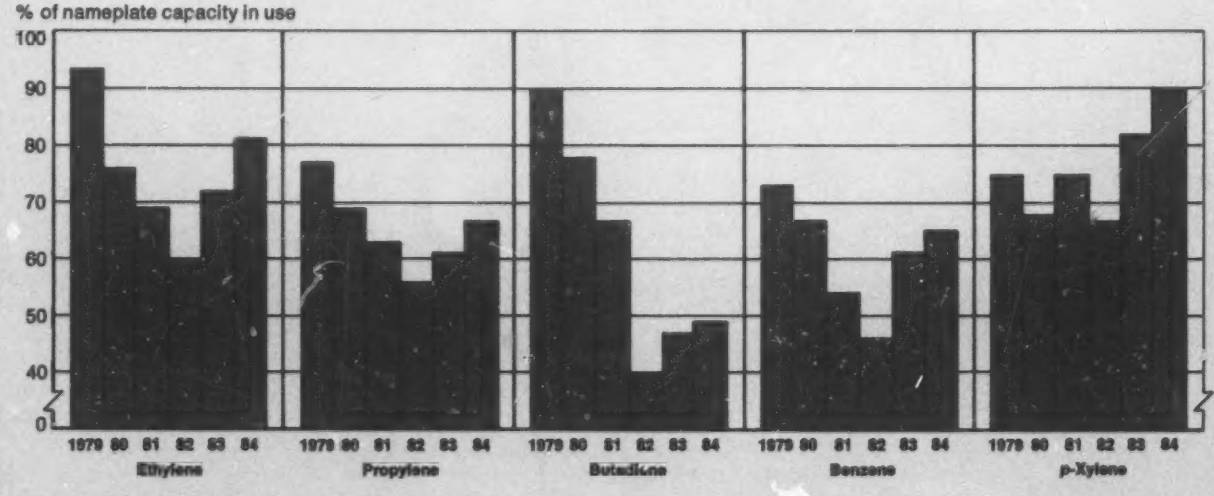
Key Chemicals

Overall performance for the five leading petrochemicals has been a surprise for analysts, who generally feared just a 5 to 10% output gain this year over the very poor showing in 1982. Instead, combined production for the five chemicals is jumping 15%, from 51 billion lb to nearly 59 billion lb. Value of production is up even more because of higher prices. Estimated combined value in 1983 will exceed $12.5 billion, up almost 20% from 1982. These estimates assume no disruption in world oil supplies from the Iran-Iraq war.

By present forecasts for 1984, combined production of these petrochemicals could move up another 9% to 64 billion lb, close to the old production record in 1979. Production value, including estimates for selling price increases, could be up 13.5% to more than $14 billion—again, close to the all-time high in 1981.

After such performance, producers still will have considerable unused capacity but may have to think over expansion plans earlier than expected in a few cases. The most obvious is *p*-xylene, which is virtually guaranteed a snug market in 1984. Ethylene coproducts, especially propylene, may need a look, too, by the mid-1980s if the trend continues toward light feedstocks, which tend to curb coproduct production.

Plant-use rates will head up substantially as recovery rolls into 1984



Sources: Industry and C&EN estimates; International Trade Commission

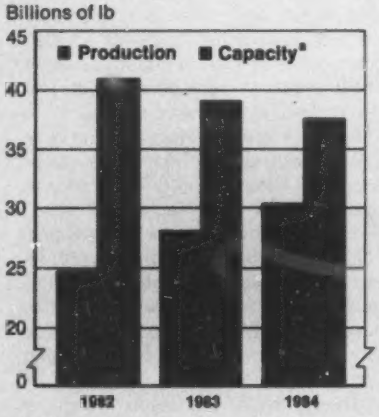
Key Chemicals

Ethylene

$CH_2{=}CH_2$

- ***Demand stronger***
- ***Capacity falling***
- ***Prices higher***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Thermal (steam) and catalytic cracking of hydrocarbons ranging from natural-gas-derived ethane to oil-derived gas oil (fuel oil)

MAJOR DERIVATIVES (U.S.)

Polyethylene 45%, ethylene oxide 15%, vinyl chloride 15%

MAJOR END USES (U.S.)

Fabricated plastics 65%, antifreeze 10%, fibers 5%, solvents 5%

FOREIGN TRADE

Negligible

PRICES

List prices between 26 and 27 cents per lb; continued discounting

COMMERCIAL VALUE

$6 billion for production, 1983

The kingpin of U.S. organics is about midway through recovery, with production moving up at more than double the long-term growth rate. Ethylene won't barrel along like this forever, but above-average growth looks guaranteed through 1984. Combined with a sharp cut in capacity, this gain is rapidly pushing up plant operating rates and restoring long-lost financial health.

The upshot is that ethylene's four-year nightmare since 1979 is finally over. At its worst in 1982, this savage interlude plunged production to little more than half of capacity and prices to discounts of 40%. Up to a quarter of capacity was shut down, some for keeps. Profits disappeared.

However, this dark chapter yielded faster than forecast to the present hopeful scene, and ethylene has a good shot at a new production record next year. For 1983, production probably will top 28 billion lb, up 14% from the very poor 24.7 billion lb in 1982. In turn, 1982 production was off 16% from 1981, the last year of fairly high operating rates. The production record remains 29.9 billion lb in 1979. Present forecasts for next year's production cluster around 30 billion to 31 billion lb, up another 10% or so from 1983.

As might be expected during a long recession-racked period, the operating economics of ethylene production units were scrutinized after 1979. Some units didn't pass muster and were shut down, either permanently or for long periods of mothballing. How much of this shutdown capacity will run again is undecided, but could get clearer soon as demand improves.

As 1983 began, some 2 billion lb per year of nameplate capacity already had come off the former official total of 41 billion lb. More dropouts showed up this year, and there could even be a few in 1984. In addition, some capacity is still down that normally would be operating if demand were higher. Probably 3 billion to 4 billion lb of capacity is out now for extended maintenance or modification to improve overall efficiency, including feedstock use.

Most such sidelined units are likely to be operating in 1984. They either will replace units now running that need maintenance or simply add capacity as needed to meet demand. One example of a steam cracker that has been down for some time is Arco Chemical's big second unit at Channelview, Tex., which is due for startup soon. When that happens, the first unit at the site is scheduled to go down for maintenance.

On a total nameplate basis, with a rough prorating for units operating only part of the year, the average operating rate for 1983 is about 75%. Most units actually are running higher than this, but most also are taking at least a month's down time.

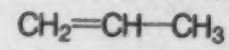
In 1984, most of these units will run most of the year with only a few sidelined for major modification. One reason is that production next year could exceed demand, due to inventory building. This contrasts with 1983, when producers continued to trim inventories in the first half. In fact, ethylene demand in 1983 could be 1 billion lb greater than production because of this inventory liquidation. Inventories are now considered rock bottom.

An inventory push next year will help boost capacity use to more than 80% of the nameplate total. This level will be a dramatic improvement from the depths of 1982, when plant use sank below 60% part of the year. Since maximum output from ethylene plants in a year like 1979 was a bit more than 90% of capacity, producers may be able to fill another year or two of demand growth after 1984 with current capacity but only if all of it comes back on stream.

Most major products made from ethylene are doing well now. In one case, vinyl chloride output seems to have leveled off after an impressive spurt in the second quarter. Polyethylene, which accounts for nearly half of ethylene use, continues in strong demand. Ethylene oxide has lagged in the recovery because downstream antifreeze and polyester fiber producers took some time to reduce inventories, but both of these outlets are expected to provide good demand for ethylene in 1984.

These and other catch-up situations will propel ethylene through another year of unusually strong growth, industry analysts predict. By the end of 1984, the demand pipelines for derivatives again will be filled, and ethylene growth will throttle back to longer-term rates, now forecast at 4 to 5% per year through the 1980s.

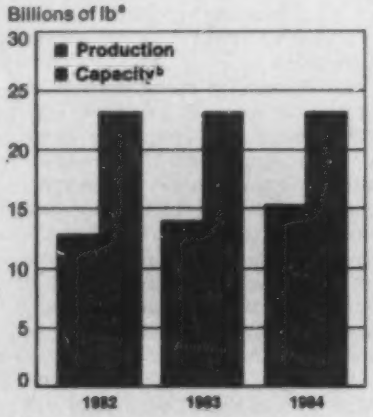
Key Chemicals



Propylene

- ***Demand back up***
- ***Capacity flat***
- ***Prices up a bit***

PRODUCTION/CAPACITY



a Chemical and polymer grades. b First quarter.

HOW MADE

Recovered from cracked gas streams made in steam-cracking olefins plants and oil refineries

MAJOR DERIVATIVES (U.S.)

Polypropylene 25%, acrylonitrile 20%, cumene 10%

MAJOR END USES (U.S.)

Fabricated plastics 50%, fibers 15%

FOREIGN TRADE

Exports—negligible, imports—holding at about 500 million lb in 1983

PRICES

Chemical grade 19.5 to 21.0 cents per lb, polymer grade 21.0 to 23.0; continued discounting

COMMERCIAL VALUE

$3 billion for production, 1983

Propylene's recovery is slightly slower than ethylene's, but doesn't have as far to go. Propylene will get close to its old U.S. production high this year and easily set a new record in 1984. In fact, because of certain supply oddities, the propylene market could get a bit snug next year, and new capacity is nowhere in sight. Upward price pressure is a good bet.

Propylene's usable spare capacity is less than ethylene's, even though official capacity use is lower, because of propylene's peculiar nature as a coproduct wherever it is produced. Propylene supply is determined not so much by propylene demand but by demand for ethylene and gasoline, the primary products of the olefin plants and refineries producing propylene.

Propylene supply is also strongly affected by the great variety of feedstocks for ethylene. When ethylene and gasoline markets are weak as in the past recession and when ethylene feedstocks favor light liquids from natural gas as in the past several years, much less propylene is available than total capacity indicates. A lot of propylene capacity is, in fact, shut down.

Earlier in 1983, shifts in feedstock costs for steam-cracking olefins plants led to use of the maximum amount of light hydrocarbons, pushing propylene coproduct output very low. At the same time, oil companies anticipated flat gasoline demand, so refineries producing propylene operated at very low levels. All told, propylene output actually ran below demand, especially when chemical and polymer uses of propylene began pulling out of the recession.

Two things happened. Propylene inventories were drawn down to minimum levels by the end of the second quarter. And propylene users substituted some refinery-grade propylene for chemical-grade propylene in making derivatives that could stand the switch.

So where does that leave full-year 1983 estimates for propylene supply and demand? More murky than ever, say analysts of this elusive petrochemical. They say that production estimates based on official data from the U.S. International Trade Commission are low because not all propylene used in chemicals is being reported.

Industry estimates of propylene production for chemical and polymer grades run around 14 billion lb for 1983. Guesses on additional propylene used for chemicals add another half a billion pounds and perhaps more.

Plant capacity for propylene in various grades is essentially unchanged from last year, at about 23 billion lb per year. Some of this capacity can't run because some steam crackers are still shut down and some refinery units cracking heavier hydrocarbons are also down. Little change in capacity seems likely soon, in part because of this overhang of shut-down capacity.

Refiners are beginning to run propylene units harder because they want additional income and profit from propylene as the gasoline market slows. Prices are moving up for several propylene derivatives, notably polypropylene, the largest nonfuel use. Higher derivative prices allow propylene producers to get higher prices too for their product. Both list and actual selling prices have increased.

These price increases generally haven't slowed the demand gains for propylene. Another 10% production gain in 1984 seems likely especially if producers start building inventories. This gain will bring the total chemical and polymer grades production to at least 15.4 billion lb. It might mean futher increases in selling prices, too.

Such production next year would push average plant operating rates close to the late-1970s' highs, which never went much over 70%. Ordinarily, these use levels might suggest time had come for expansion. But most propylene producers will feel added investment really isn't needed and will continue to make good returns from existing investment all through 1984.

For propylene customers, a favorable situation for producers will mean a careful watch on supplies. It is not out of the question that propylene could get tight in the next year or two, with a sizable jump in price. At the moment, propylene prices are back down to their 20 to 30% level below ethylene prices. But propylene users remember what happened in 1982, when a crimp on coproduct propylene production forced propylene prices into an unprecedented premium over ethylene. This hurt performance in many derivatives.

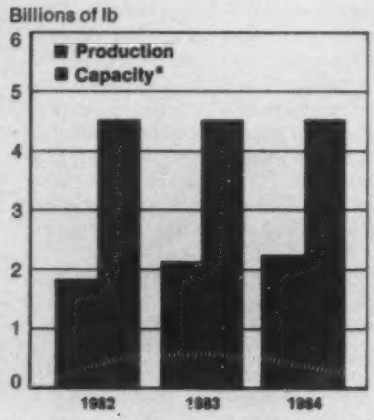
Key Chemicals

Butadiene

$CH_2{=}CH{-}CH{=}CH_2$

- ***Production low***
- ***Capacity flat***
- ***Prices off a bit***

PRODUCTION/CAPACITY



a First quarter; includes all extraction capacity.

HOW MADE

Recovered from steam-cracker product streams; dehydrogenation of butylenes made in oil refineries

MAJOR DERIVATIVES (U.S.)

Styrene-butadiene rubber 40%, polybutadiene rubber 20%

MAJOR END USES (U.S.)

Rubber products 70%, fibers 10%

FOREIGN TRADE

Exports—holding at about 70 million lb in 1983, imports—rising to more than 900 million lb

PRICES

List price 34 cents per lb; discounts general

COMMERCIAL VALUE

$650 million for production, 1983

As usual, butadiene is the maverick of the petrochemical business. It isn't recovering well and may have some bad news in store, the main culprit being imports. With no relief in its dominant rubber market, butadiene may start to lose plant capacity, much of which is shut down anyway. Altogether, butadiene is a case in which coproduct status and single-market dependence add up to a no-win situation.

About 70% of U.S. butadiene use is in rubber products, and more than 40%—production plus sizable imports—goes into styrene-butadiene rubber. Most of this rubber goes to transportation uses—tires and other fabricated rubber products in cars and trucks. So as transportation goes, so goes butadiene demand.

Large cuts in auto production in 1982 and moderate recovery in 1983 tell the tale for butadiene, too. Butadiene output fell 40% last year to 1.8 billion lb and will recover only 17% this year to about 2.1 billion lb. Plant capacity of 4.5 billion lb per year is running at a lowly 47%.

Why butadiene producers are caught with more than twice the plant capacity they really need becomes clear with a few seconds' glance at butadiene history. U.S. production actually peaked back in 1974 at 3.7 billion lb. Since then, output fell sharply in the 1975 recession, recovered most of the way by 1979, and then collapsed to half the old peak by 1982. Butadiene could get none of the new growth in the past decade in other U.S. organics because of the growing plight of the U.S. auto industry and the bulging forced butadiene surplus in Europe.

Aggravating the situation are certain current trends in the transportation industry. For example, changes in tire design are eroding demand for rubber, especially styrene-butadiene rubber. And almost all new cars produced in the 1983 model year are equipped with radial tires, which get much improved tread life. These two factors combined to reduce styrene-butadiene rubber production slightly in the first half of 1983 from first-half 1982. They also kept down possible gains in production of polybutadiene, an important part of tread rubbers.

Tires also are lasting longer simply because they aren't used as much as in the past. Last year continued the recent trend of fewer miles driven per car. This further reduces demand for tires in the replacement market, in turn reducing rubber and butadiene demand.

If these market forces weren't bad enough, butadiene's foreign trade adds another big dent for U.S. production. In 1982, more than a quarter of butadiene consumed in the U.S. was imported, mostly from Europe. Such imports were up 75% over 1981. In 1983, imports may be up another 20%. The reason is that European operators of steam-cracking olefins plants, which still are fed largely naphtha, need a foreign outlet for their large excess of butadiene coproduct. The U.S. is their sink, and U.S. butadiene imports of more than 900 million lb in 1983 will fill nearly 30% of demand, which is estimated at 3.0 billion lb or a bit more.

Partly because of imports, U.S. butadiene inventories are swelling. As the third quarter ended, inventories may have reached nearly a month's supply, considered high by most industry analysts. So inventories are dampening production plans for the rest of 1983.

With production badly crimped, the ax finally may fall on butadiene capacity, the independent part of which frequently has languished on standby in recent years. At this time, all stand-alone dehydrogenation units are believed shut down. (At some of these plants, the extraction sections may be running on C_4 hydrocarbons streams brought in from outside sources, including foreign plants.) Restarting these shut-down units is questionable for most. Even so, actual scrappage may take some time, since these units are easy to start up and run and represent little capital investment.

In the event that markets for coproduct butadiene and propylene tighten up and prices jump, steam crackers could be fed heavier hydrocarbons so that coproduct yield would increase. But industry analysts say that this won't happen for the rest of 1983 and at least the first quarter of 1984.

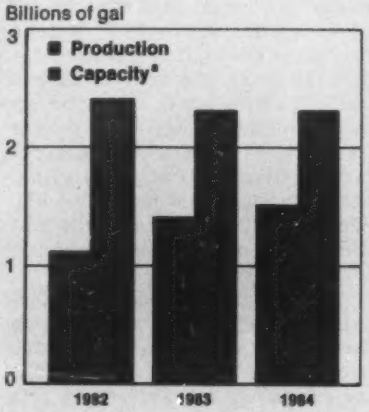
The net influence of these supply and demand factors will be a near standstill for U.S. butadiene production, analysts estimate. Imports will take care of any increase in demand, and inventories will remain large. Butadiene will be a buyer's market, and it will be priced to move.

Key Chemicals

Benzene

- ***Demand well up***
- ***Capacity flat***
- ***Prices up***

PRODUCTION/CAPACITY



a First quarter; includes all sources.

HOW MADE

Separated from aromatics streams from refineries, olefins plants, coke ovens; dealkylation of toluene

MAJOR DERIVATIVES (U.S.)

Ethylbenzene 50%, cumene 20%, cyclohexane 15%, aniline 5%

MAJOR END USES (U.S.)

Styrenic plastics 35%, phenolic polymers 20%, nylon 15%

FOREIGN TRADE

Exports—small, imports—down a bit to about 100 million gal in 1983

PRICES

List price up to $1.55 per gal

COMMERCIAL VALUE

$2 billion for production, 1983

Like its olefin cousins, benzene has enjoyed a sharp rebound this year, but its recovery isn't nearly as far along as is ethylene's. There is simply too much ground to regain: U.S. benzene output fell 36% from 1979 to its low point in 1982. So even an 18% pickup this year will leave benzene well short of full recovery, well shy of full capacity use, and only slightly firmer in its pricing.

Further, industry people close to benzene say that its recovery pace has slackened in recent months. At the moment, these sources are cautious about 1984, predicting a gradual flattening in year-to-year comparisons of benzene production. A differential has begun to show up in the performance of benzene's major derivatives. Some—for example styrene, made via ethylbenzene—are still doing well, but others such as phenol are posting just small gains in demand for benzene compared to a few months ago.

All told, benzene production in 1983 will exceed 1.3 billion gal and possibly 1.4 billion gal by some optimists' forecasts. That's up from less than 1.1 billion in 1982. However, for 1984, analysts expect only about half the 1983 production gain for a total of 1.5 billion gal. Some forecasts are not this high and indicate a production gain of only 50 million to 100 million gal, barring some fresh thrust in the general U.S. economy.

At the 1983 and predicted 1984 production levels, benzene's capacity use will remain fairly low, not much above 60%. This will leave plenty of room for new production growth, even though benzene, like propylene, cannot in practice run much more than 75% of nameplate capacity even in the best of years. For example, in a very tight market in 1979, benzene capacity use hit a high point of about 77%.

An added drag on capacity use comes from benzene's and its derivatives' foreign trade. Benzene itself has a significant trade deficit after little influence from trade in the late 1970s. Even with a 10 to 20% decline in 1983, benzene imports will be about 100 million gal. Benzene's exports are tiny, below 10 million gal.

Benzene derivatives add little cheer to the export picture. Styrene still may have large exports this year, but a decline is generally expected after that. Big drops already have come for other derivatives, including cyclohexane, nylon, and phenol.

Despite these market holes, capacity to make benzene remains about constant at 2.3 billion gal per year. The vast majority of benzene supply will come as usual from petroleum sources. And, as usual, reformate-derived benzene from petroleum refining will account for about half the supply for chemical uses. Pyrolysis gasoline from steam-cracking olefins plants will account for another quarter of supply, and dealkylation of toluene in independent plants will provide much of the remainder. Coke ovens will account for 5 to 7% of production, up from 1982 but still a small part of the total.

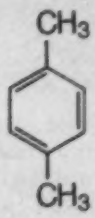
Only minor changes are due in benzene capacity. These will reflect changes mainly in operating conditions at the steam crackers. For example, there are seasonal fluctuations in benzene production from the crackers as operators shift slightly to lighter hydrocarbon feedstocks during the winter months and to heavier feedstocks in summer. The heavier feedstocks, which yield more benzene, are more economical for chemical use in the summer when their competing outlet in fuel oil is low.

In the non-steam cracker capacity for benzene, refinery sources are not expected to change very much. The independent hydrodealkylation plants may not run very hard, unless cost of feedstock toluene becomes quite attractive, but plant owners are unlikely to scrap these units either. Coke oven operators producing by-product benzene may have a lot of capacity that will never run again, considering the distress conditions in the ovens' main outlet, steel.

For consumers, of course, large U.S. overcapacity in benzene is a good deal. Consumers will continue to see quick deliveries and strong price competition this year and next. This month, list prices for benzene generally increased to $1.55 a gal, up a nickel. Competition will keep spot prices a bit below list after this increase, at least for a while, with variations depending on the level of petroleum refining operations and gasoline demand. Big upward price pressure isn't likely in 1984.

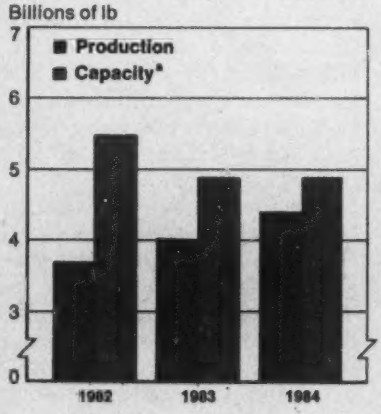
Key Chemicals

p-Xylene



- ***Demand swelling***
- ***Capacity use tightening***
- ***Prices pointing up***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Separated from mixed xylene streams made in oil refineries and steam-cracking olefins plants

MAJOR DERIVATIVES (U.S.)

Dimethyl terephthalate 55%, terephthalic acid 45%

MAJOR END USES (U.S.)

Polyester fibers, film, and fabricated items (mostly bottles) almost 100%

FOREIGN TRADE

Exports—down to about 600 million lb in 1983, imports—small

PRICES

List price 26.5 cents per lb; discounts lessening

COMMERCIAL VALUE

$1 billion for production, 1983

p-Xylene has staged a dramatic turnaround in 1983 and could go into tight supply in 1984. That's quite a change from its bedraggled condition in 1982, when production slumped 37% from the old high of 4.7 billion lb in 1979. Back-to-back production rebounds of 10% in 1983 and 1984 will combine with a nearly 15% drop in plant capacity to catapault capacity use from 67% in 1982 to an expected 90% or higher.

Besides showing the value of an occasional capacity shakeout, which has proved very healthy for survivors, *p*-xylene is benefiting for once from its single-market dependence on polyesters. After falling 24% in the 1982 recession, polyester fiber demand is up nearly 10% so far in the Textile Economics Bureau's tabulations for 1983. The smaller market for *p*-xylene in polyester bottles, which rose even in the recession, is gaining strongly again this year and could be one of the fastest growing commodity chemical markets of the 1980s.

For *p*-xylene, such market health is causing a production leap from 3.7 billion lb in 1982 to more than 4.0 billion lb in 1983 and at least 4.4 billion lb in 1984. If the rosiest forecasts are right with production of 4.5 billion lb next year, *p*-xylene's capacity use would hit 92% of the first-quarter nameplate total of 4.9 billion lb per year. That's a flat-out rate. The squeeze would be on for customers, and producers might resort to cutting *p*-xylene exports to fill U.S. demand.

Customers will get some relief next year from added *p*-xylene capacity. Exxon Chemical will add some 150 million lb a year in an expansion and modernization project now under way at Baytown, Tex. If completed in early 1984 as scheduled and started up with minimum difficulties, this project could add possibly 100 million lb to 1984 *p*-xylene production. In another expansion, Chevron Chemical plans an additional 70 million lb of capacity at Pascagoula, Miss., to start up in late 1984.

Beyond these specific projects, some debottlenecking may be possible at other producers, especially those with relatively new plants. Industry sources suggest that demand pressures could add 5% to capacity this way without long shutdowns. One caveat for customers is that, if demand for *p*-xylene is very high, producers will have an incentive to run units longer than normal before maintenance shutdowns, making shutdowns longer than usual when they finally occur.

On balance, analysts guess that *p*-xylene might just squeak through 1984 with supply successfully pushed up to meet demand. One further aid may be completion of *p*-xylene plant projects abroad, which would take some of the pressure off U.S. *p*-xylene exports. Exports have run 20% of U.S. production in the past but may now ease down to 15% or less.

Markets for *p*-xylene will be up on all sides in 1984, analysts forecast. For example, polyester for fibers is due for a significant pickup in exports to China, which stopped importing U.S. product in 1982 and 1983 while negotiating a new textile trade agreement with the U.S. The pact is now in hand, and the Chinese are expected to take a large volume of U.S. polyester in 1984. These exports may offset a somewhat reduced recovery rate expected for polyester fiber in the U.S. next year.

The U.S. polyester beverage bottle business will continue its handsome growth in 1984 as one of the few new large-volume commodity chemical markets of recent years. One slight brake on this new growth is that, to cut costs of the finished bottles, fabricators are testing multilayer bottles made with polyethylene and a polyester barrier layer. However, analysts believe such new hybrid plastic bottles probably won't affect *p*-xylene demand very much in 1984.

In sum, *p*-xylene may be the first basic U.S. petrochemical to fully extricate itself from the prevailing gloom of the early 1980s and become a robust business as in brighter chemical decades of the past. A large part of *p*-xylene's secret is good long-term growth, which has made the chemical's strong tie to polyester an asset, even if a risky one in recessions. With by far the strongest volume growth in the past decade among the five major basic petrochemicals, *p*-xylene will have output in 1984 double that of the early 1970s. Only propylene is within hailing distance. And *p*-xylene likely will reach new production highs in 1985.

Turnaround ahead for antioxidants use

U.S. consumption of antioxidants to stabilize plastic resins will grow 4.7% per year to 44 million lb in 1986, worth $147 million, from 35 million lb in 1981, valued at $88 million. This is the estimate of Roger Lacallade, market manager for specialty chemicals at Uniroyal Chemical, Naugatuck, Conn. He chose 1981 as a base year because the recent recession depressed sales to an abnormally low 32 million lb, which sold for $78 million.

Recovery of such polyolefin markets as automotive and housing likely will bring upturns in the antioxidants compounded into them by resin producers. "But it could be stifled or stopped flat," Lacallade warns, "by the huge federal deficit and fiscal and monetary policies." Assuming a mild economic recovery, however, he goes on to make predictions about antioxidants sales performances.

Lacallade notes that in polyolefins, a key market for antioxidants, imports are growing fast. This has a negative impact on U.S. antioxidant consumption. "But we see growth in domestic linear low-density polyethylene production as being able to offset this at least a little." Too, a rapid rise in the market share of polyvinyl chloride (PVC) for pipe has cut into antioxidant sales for acrylonitrile-butadiene-styrene (ABS) resin in this use. But on a more positive note, Lacallade adds, "In any case, we don't see foreign competition being as severe a threat to styrenics as to polyolefins."

A pattern of antioxidant use in various resins has been developed by the research and consulting firm SRI International, Menlo Park, Calif. Polypropylene takes 33% of all antioxidants and requires higher loadings than many other polyolefins. This is because the highly branched structure of this polymer contains many tertiary carbon atoms, which are prime sites for radical and peroxide formation. ABS also needs large amounts owing to the carbon-carbon double bonds present. About 19% of antioxidants are used in ABS, according to SRI. PVC accounts for 16%, such other polyolefins as polyethylene for 15%, high-impact polystyrene for 12%, and other resins for 5%.

The biggest single class of antioxidants for plastic resins is hindered phenols, including butylated hydroxytoluene (BHT). This class comprised 57% of the pounds and 75% of the dollars of U.S. antioxidant sales in 1981, a relative position that will be maintained through 1986. Lacallade estimates that high-molecular weight diphenols and polyphenols will grow at 5.7% per year in the period, but use of BHT itself will increase only 2% annually. This is because low-molecular-weight BHT is limited to resins that process at 300 to 400 °F. Too, there have been shortages in raw material *p*-cresol and decreases in BHT capacity. Principal U.S. producers of BHT for this industry are Koppers, Sherwin-Williams, and Uniroyal Chemical, which have 80% of the market, according to Lacallade. For other hindered phenols, he estimates that Ciba-Geigy sells 50% of the total, and Ethyl and B. F. Goodrich together account for another 20%.

These hindered phenols are primary antioxidants, which means that they work by quenching free radicals. Radicals trigger polymer degradation. Such secondary antioxidants as thioesters and organophosphites destroy peroxides, which might otherwise form radicals. Lacallade estimates that use of thioesters like distearyl β,β'-thiodipropionate will grow only 2.5% per year through 1986, whereas organophosphites like tris(nonylphenyl) phosphite will forge ahead at 7.4% yearly. This is because thioesters are antagonistic toward the hindered amine ultraviolet light absorber additives now becoming so popular. Thus many resin producers will reformulate around organophosphites. American Cyanamid and Evans Chemetics, a subsidiary of W. R. Grace, have 75% of the U.S. market for thioesters for plastic resins, Lacallade says, and Borg-Warner and Uniroyal Chemical sell 75% of the organophosphites.

For their own part, Uniroyal Chemical managers pin their hopes on a recently introduced hindered phenol that doubles as a metal deactivator. Metal deactivators chelate metals like iron and copper, which are capable of more than one oxidation state, and which thus might catalyze resin autooxidation. Sources of such metals are pigments, fillers, and polymerization catalyst residues.

The Uniroyal compound is *N,N'*-oxamidodiethyl 3-(3,5-di-*tert*-butyl-4-hydroxyphenyl) propanoate. The company also has just introduced a synergistic blend of that compound with tris(2,4-di-*tert*-butylphenyl) phosphite, which is a solid organophosphite. These products are part of Uniroyal Chemical's overall effort to develop more high-performance hindered phenols and organophosphites, while remaining strong in such work-horse products as BHT and tris(nonylphenyl) phosphate. Both products have gotten Food & Drug Adminmistration approval. Uniroyal Chemical marketing specialist Gerald J. Hollmann says that these approvals open up the entire potential 12 million lb-per-year market in non-BHT-hindered phenols to these products. This is because plastic processors will have assurance of the overall safety of these additives even when used in other than food and drug applications. □

Antioxidant market will be 44 million lb in 1986 . . .

Millions of lb	1981	1982	1986
BHT[a]	7.7	6.8	8.5
Hindered phenols[b]	12.3	11.4	16.2
Phosphites	7.0	6.4	10.0
Thioesters	6.0	5.3	6.8
Other	2.0	1.8	2.5
TOTAL	35.0	31.7	44.0

. . . and will be worth about $147 million

$ millions	1981	1982	1986
BHT[a]	$12.8	$10.2	$ 15.9
Hindered phenols[b]	52.9	47.9	93.2
Phosphites	8.1	7.4	15.7
Thioesters	10.2	8.9	15.3
Other	4.0	3.4	6.7
TOTAL	$88.0	$77.8	$146.8

a Butylated hydroxytoluene. b Other than BHT.
Source: Uniroyal Chemical